(12) PATENT (11) Application No. AU 199658151 B2
(19) AUSTRALIAN PATENT OFFICE (10) Patent No. 701955

(54) Title
Energy saving process

(51)[6] International Patent Classification(s)
F25J 001/02 F25J 003/02

(21) Application No: 199658151 (22) Application Date: 1996.05.07

(87) WIPO No: WO96/35914

(30) Priority Data

(31) Number	(32) Date	(33) Country
19517116	1995.05.10	DE

(43) Publication Date : 1996.11.29
(43) Publication Journal Date : 1997.01.23
(44) Accepted Journal Date : 1999.02.11

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(56) Related Art
US 5139548
JP 58-098606
EP 143267

OPI DATE 29/11/96 APPLN. ID 58151/96
AOJP DATE 23/01/97 PCT NUMBER PCT/EP96/01909

AU9658151

(51) Internationale Patentklassifikation 6 :
F25J 1/02, 3/02

A1

(11) Internationale Veröffentlichungsnummer: WO 96/35914

(43) Internationales Veröffentlichungsdatum: 14. November 1996 (14.11.96)

(21) Internationales Aktenzeichen: PCT/EP96/01909

(22) Internationales Anmeldedatum: 7. Mai 1996 (07.05.96)

(30) Prioritätsdaten:
195 17 116.0 10. Mai 1995 (10.05.95) DE

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(81) Bestimmungsstaaten: AL, AM, AT, AU, AZ, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO Patent (KE, LS, MW, SD, SZ, UG), eurasisches Patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches Patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI Patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Veröffentlicht
Mit internationalem Recherchenbericht.
Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist. Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: ENERGY SAVING PROCESS

(54) Bezeichnung: VERFAHREN ZUR VERRINGERUNG DES ENERGIEVERBRAUCHS

(57) Abstract

A process is disclosed to reduce the energy consumed by a cooling and/or liquefying process, in particular natural gas cooling and/or liquefying process coupled to a refrigeration cycle that supplies the energy required for the cooling and/or liquefying process. The process is characterised in that (a) the combustion air supplied to the gas turbine in the refrigeration cycle is previously cooled either directly by means of a separate auxiliary refrigeration cycle or through at least one additional (brine) refrigeration cycle; and (b) the medium to be cooled and/or liquefied is also previously cooled.

(57) Zusammenfassung

Verfahren zur Verringerung des Energieverbrauchs eines Abkühl- und/oder Verflüssigungsprozesses, insbesondere eines Abkühl- und/oder Verflüssigungsprozesses von Erdgas, gekoppelt mit einem Kältekreislauf-Prozeß, der der für den Abkühl- und/oder Verflüssigungsprozeß notwendigen Energiebereitstellung dient, wobei a) mittels eines separaten Hilfskältekreislaufes auf direktem Wege oder durch Zwischenschalten wenigstens eines weiteren Kälte(sole)kreislaufs ein Vorkühlen der der Gasturbine des Kältekreislauf-Prozesses zugeführten Verbrennungsluft sowie b) ein Vorkühlen des/der abzukühlenden und/oder zu verflüssigenden Mediums/-ien erfolgt.

Description

Method for Cooling and/or Liquefying a Medium

The invention is directed to a method for cooling and/or liquefying a medium, in particular natural gas, where the cooling and/or liquefaction of the medium is accomplished by indirect heat exchange with the refrigerant or the refrigerant mixture of at least one refrigerating cycle, and where the refrigerating cycle has at least one compressor which is driven by at least one gas turbine which is supplied with combustion air in addition to a fuel.

In conventional low-temperature processes, such as the liquefaction of natural gas, the crude gas is usually supplied to the low temperature process at ambient temperature and is only then cooled and liquefied in the so-called "cold" phase of the process. The refrigeration required for the cooling or liquefaction of the crude gas is provided by a usually closed refrigerating cycle. The compression of the circulating refrigerant can for instance be carried out by gas turbine drives. The air required here for combustion is sucked in at ambient temperature. In EP-PS 0 143 267 a liquefaction process for natural gas is described in which the natural gas to be liquefied is cooled and liquefied by using two closed cycles in which multi-component refrigerants are circulated. From US-PS 5 139 548, a liquefaction process for natural gas is known where the precooling of the natural gas to be liquefied is achieved by means of a propane refrigerating cycle and the liquefaction and subcooling of the precooled natural gas is achieved by means of a refrigerant mixture cycle. For such a liquefaction process the refrigerating energy required for the liquefaction is thus provided by means of a refrigerating cycle cascade.

It is the object of the present invention to specify a method which reduces the energy consumption of a cooling and/or liquefaction process which is coupled with a refrigerating cycle process.

According to the present invention, this is accomplished in that at least one separate auxiliary refrigerating cycle is provided, which, by indirect heat exchange, serves to precool the

combustion air supplied to the gas turbine and the precooling of the medium/media to be cooled and/or liquefied.

Alternatively, at least one separate auxiliary refrigerating cycle and at least one separate brine cycle can be provided, where the auxiliary refrigerating cycle serves the cooling of the brine of the brine cycle, where the auxiliary refrigerating cycle or the brine cycle, by indirect heat exchange, serve to precool the combustion air supplied to the gas turbine and the auxiliary refrigerating cycle or the brine cycle, by indirect heat exchange, serve to precool the medium/media to be cooled and/or liquefied.

The invention as well as further embodiments thereof are described in greater detail with reference to Figures 1 and 2.

Fig. 1 shows a liquefaction process for natural gas, as it is used for instance in LNG-Baseload systems. Fig. 2 shows a N_2/C_{1+} -separation process, as it is used for instance in the separation of nitrogen from natural gas.

In the process mentioned in accordance with Fig. 1 the natural gas stream supplied via line 1, in a carbon dioxide wash A, is initially freed of any carbon dioxide it may still contain. When leaving the carbon dioxide wash A the natural gas

stream still has a temperature of 313 K. Subsequently, the natural gas stream freed of carbon dioxide is supplied via line 2 to a heat exchanger B. In this heat exchanger it is cooled by 30°K in a counterflow to the refrigerant of a separate auxiliary refrigerating cycle which shall be discussed in more detail below. The cooled natural gas stream is then supplied to a separator C where the water resulting in the separator is then supplied back to wash A via line 4 shown as a broken line. The natural gas stream withdrawn from the head of separator C is then supplied via line 3 to a dehumidifier D. Here the natural gas stream is dehumidified, preferably by way of adsorption. Subsequently, the precooled natural gas stream is supplied via line 5 to a heat exchanger E, where it is cooled and liquefied further against the process refrigerating cycle which shall also be discussed in more detail below. The liquefied natural gas is withdrawn from heat exchanger E via line 6 and supplied for its further utilisation to, for instance, temporary storage in a LNG tank. As the temporary storage in the LNG tank may be at atmospheric pressure, for instance, the liquefied natural gas is initially expanded through a valve F to the pressure existing in the LNG tank and subsequently supplied to the LNG tank via line 7. The process refrigerating cycle required for further cooling and liquefying the natural gas contains a refrigerant which is a mixture of hydrocarbons or nitrogen and hydrocarbons. In the present case, the refrigerant mixture is compressed in two stages (H, H'). After the first compression in compressor H, the refrigerant mixture is supplied via line 8 to an air cooler J, where it is cooled against ambient air and is subsequently supplied to the second compression stage H'. After the refrigerant mixture has been withdrawn from its second compression stage H' via line 9, it is again supplied to the air cooler J mentioned above and subsequently via line 10 supplied to a heat exchanger K, where it is cooled against the cooling medium of a brine cycle, which shall also be discussed in more detail below. The precooled refrigerant mixture is subsequently supplied via line 11 to heat exchanger E, cooled under high pressure and, depending on the particular embodiment of the process, will be expanded through valves L and/or L' and heated against the natural gas stream in line 5 which is to be cooled and liquefied, and against the high-pressure refrigerant stream in line 11. Subsequently, the refrigerant stream is again supplied to the first compression stage H via line 12. The two-stage compression (H, H') is driven by a gas turbine G to which combustion air is

supplied via line 13. Before its supply to the gas turbine, the combustion air supplied via line 13 is cooled against a part stream of the already mentioned brine cycle in heat exchanger K'. The requisite amount of combustible gas is supplied via line 15, whilst line 16 is the exhaust pipe. The brine cycle mentioned above, whose cooling medium can, for instance, be a mixture of ethylene glycol and water, can be selected for safety considerations. The cooling medium of this brine cycle is supplied via line 20 to a pump M in order to increase the pressure and subsequently via line 21 to a heat exchanger N. Here the brine is cooled in counterflow to a part stream of the previously mentioned auxiliary refrigerating cycle which, as previously mentioned, serves to precool the natural gas stream. The brine is withdrawn from heat exchanger N via line 22 and via line 23 is partly supplied to heat exchanger K and partly to heat exchanger K'. The portion of the brine withdrawn from heat exchanger K via line 20 is admixed to the remainder of the brine withdrawn from heat exchanger K' via line 24.

The previously mentioned auxiliary refrigerating cycle contains as refrigerant a pure substance which is liquefiable at ambient temperature, such as propane, or a mixture which is liquefiable at ambient temperature. The refrigerant is supplied to a compressor O via line 30, subsequently supplied to an air cooler P via line 31 and then to a receiver Q. From this receiver liquid refrigerant is withdrawn via line 33 and after passage through a pump R is supplied via line 34 to a branch point. A portion of the refrigerant is cooled and expanded through a valve S and is supplied via line 35 to the previously mentioned heat exchanger N. In this heat exchanger the refrigerant is heated against the brine cycle medium to be cooled. The heated refrigerant of the auxiliary refrigerating cycle is subsequently withdrawn via line 36 and again admixed to line 30. From the previously mentioned branch point a portion of the refrigerant is supplied via line 37 to an expansion valve T, is expanded and supplied to heat exchanger B via line 38. The refrigerant heated in heat exchanger B is subsequently again supplied to line 30 via line 39.

Fig. 2, as previously mentioned, shows a N_2/C_{1+} -separation process, such as is used to separate nitrogen from natural gas. In this process the nitrogen-containing natural gas stream, from which any other undesirable components, as for instance carbon dioxide, have already been removed, is supplied via line 1 to a heat

exchanger A where it is cooled in counterflow to the medium of a brine cycle, which shall be discussed in more detail below. Subsequently, the natural gas stream is supplied via line 2 to a further heat exchanger B, where it is cooled further and is partially or completely liquefied against the process refrigerating cycle, which shall also be discussed in more detail below. The natural gas which has been partially or completely liquefied is withdrawn from heat exchanger B via line 3 and through expansion valve C and via line 4 is supplied to the top of separation column D. In separation column D the separation into a nitrogen-rich and a C_{1+} -rich fraction is achieved. The nitrogen-rich fraction is withdrawn via line 5 from the top of separation column D, in heat exchanger B is heated against the natural gas stream to be cooled and is subsequently expelled from the process via line 6. The heating of separation column D is provided by column heating E. The C_{1+}-rich fraction is withdrawn from the sump of separation column D via line 7, is pumped in pump F to the desired pressure and subsequently via line 8 is supplied to heat exchanger B. In this heat exchanger the C_{1+}-rich fraction is heated and evaporated and subsequently expelled from the system via line 9.

The refrigeration required for the cooling and liquefaction of the natural gas stream is provided by the process refrigerating cycle X. This cycle differs from the process refrigerating cycle illustrated in Fig. 1 only in as far as it has a third compression stage U in addition to the first two compression stages H and H'. This third compression stage U is driven by expansion of the refrigerant mixture in the expansion turbine V. As already illustrated in Fig. 1, the refrigerant mixture is supplied to an air cooler J after each compression stage. Immediately following this, the refrigerant mixture is each time passed through a heat exchanger K, in which the refrigerant mixture is cooled against a part stream of a brine cycle. This brine cycle as well as the auxiliary refrigerating cycle shall now be discussed in more detail. The refrigerant mixture of the auxiliary refrigerating cycle, preferably a pure substance which is liquefiable at ambient temperature, for instance propane, or a mixture which is liquefiable at ambient temperature, is supplied to a compressor L via line 10. After compression the refrigerant mixture is supplied via line 11 to an air cooler M and subsequently to a receiver N. From this receiver the liquid refrigerant mixture is withdrawn via line 13 and divided into two part streams. A first refrigerant mixture part stream is cooled and expanded

through valve O and is heated and evaporated in heat exchanger P against the brine cycle medium to be cooled. Subsequently this refrigerant mixture part stream is supplied back to compressor L via lines 15 and 10. The second refrigerant mixture part stream is supplied via line 16 to an expansion valve Q. After expansion through expansion valve Q, this refrigerant mixture part stream is supplied via line 17 to heat exchanger R, where it is heated and evaporated against the brine cycle medium to be cooled. From this heat exchanger R the refrigerant mixture is subsequently supplied to compressor L via lines 18 and 10. The brine cycle medium is supplied via line 20 to a pump S in where it is pumped to the desired pressure and supplied to the previously mentioned heat exchanger R. In this heat exchanger the brine is cooled against the refrigerant mixture of the auxiliary refrigerating cycle which is to be heated, and the brine is subsequently supplied to a branch point via line 21. At this branch point a part stream of the brine is supplied via line 22 to the also already mentioned heat exchanger P and in this heat exchanger is cooled against the refrigerant mixture of the auxiliary refrigerating cycle which is to be heated. Subsequently the brine cycle medium is again supplied to pump S via lines 23 and 20. The second part stream of the brine is withdrawn from the branch point via line 24. A part stream thereof is supplied via line 25 to the also already mentioned heat exchanger A and it is heated and evaporated against the nitrogen-containing natural gas stream which is to be cooled. The heated and evaporated brine is then subsequently again supplied to pump S via lines 26, 31, 32 and 20. A further part stream of the brine cycle medium is supplied to the also already mentioned heat exchanger K via lines 24 and 27. In this heat exchanger the brine is heated and subsequently admixed via line 28 to the brine in lines 31 and 32. A further part stream of the brine is supplied via line 29 to heat exchanger K'. In heat exchanger K' the combustion air supplied to gas turbine B is cooled. The brine cooled in heat exchanger K' is subsequently, via line 30, admixed to the brine in lines 26 and 31.

Through the precooling of the combustion air supplied to the gas turbine as well as through the precooling of the medium to be cooled and/or liquefied, and/or the process refrigerating cycle, in the examples of Fig. 1 and 2 for natural gas, a marked reduction of the specific liquefying or refrigerating capacity is achieved. Especially in large capacity systems, as for instance in LNG-Baseload systems, the overall efficiency

determines the size of the individual liquefaction lines and therefore the investment costs for such a system. By the method in accordance with this invention, in LNG-Baseload-Systems, a marked increase in the line size is achieved, and in other types of large capacity systems, a marked reduction of the specific energy consumption.

The auxiliary refrigerating cycle or the brine cycle which serves the precooling of the combustion air as well as the precooling of the medium/a to be cooled and/or liquefied can naturally also be utilised for other precooling or cooling processes. Such precooling or cooling processes are for instance the precooling of crude gas prior to entering absorbers, cooling of head products of the amine wash for the removal of carbon dioxide, subcooling of the refrigerant or refrigerant mixture, precooling of the high-pressure process refrigerating cycle etc.

The application of the method in accordance with the invention is naturally not limited to the two processes shown in Fig. 1 and 2. Its application is also particularly advantageous in liquefaction processes which utilise multi-stage propane refrigerating cycles or in processes which utilise C_2/C_3-refrigerating cycles or pure substance refrigerating cycles.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. Method for cooling and/or liquefying a medium, in particular natural gas, where the cooling and/or liquefaction of the medium is accomplished by indirect heat exchange with the refrigerant or the refrigerant mixture of at least one refrigerating cycle, and where the refrigerating cycle has at least one compressor which is driven by at least one gas turbine which is supplied with combustion air in addition to a fuel, characterised in that at least one separate auxiliary refrigerating cycle is provided which, by indirect heat exchange, serves to precool the combustion air supplied to the gas turbine and to precool the medium/media to be cooled and/or liquefied.

2. Method for cooling and/or liquefying a medium, in particular natural gas, where the cooling and/or liquefaction of the medium is accomplished by indirect heat exchange with the refrigerant or the refrigerant mixture of at least one refrigerating cycle, and where the refrigerating cycle has at least one compressor which is driven by at least one gas turbine which is supplied with combustion air in addition to a fuel, characterised in that at least one separate auxiliary refrigerating cycle and at least one separate brine cycle are provided, where the auxiliary refrigerating cycle serves to cool the brine of the brine cycle, where the auxiliary refrigerating cycle or the brine cycle by indirect heat exchange serve to precool the combustion air supplied to the gas turbine and where the auxiliary refrigerating cycle or the brine cycle by indirect heat exchange serve to precool the medium/media to be cooled and/or liquefied.

3. Method in accordance with claim 1 or 2, characterised in that the natural gas to be cooled and/or liquefied and/or the process refrigerating cycle refrigerant or refrigerant mixture represents the medium to be cooled and/or liquefied.

4. Method in accordance with any one of claims 1 to 3, characterised in that the separate auxiliary refrigerating cycle features as refrigerant pure substances liquefiable at ambient temperature, such a propane, or mixtures.

5. Method for cooling and/or liquefying a medium, substantially as hereinbefore described with reference to the drawings.

DATED this 16th day of December, 1998.

LINDE AKTIENGESELLSCHAFT

By its Patent Attorneys
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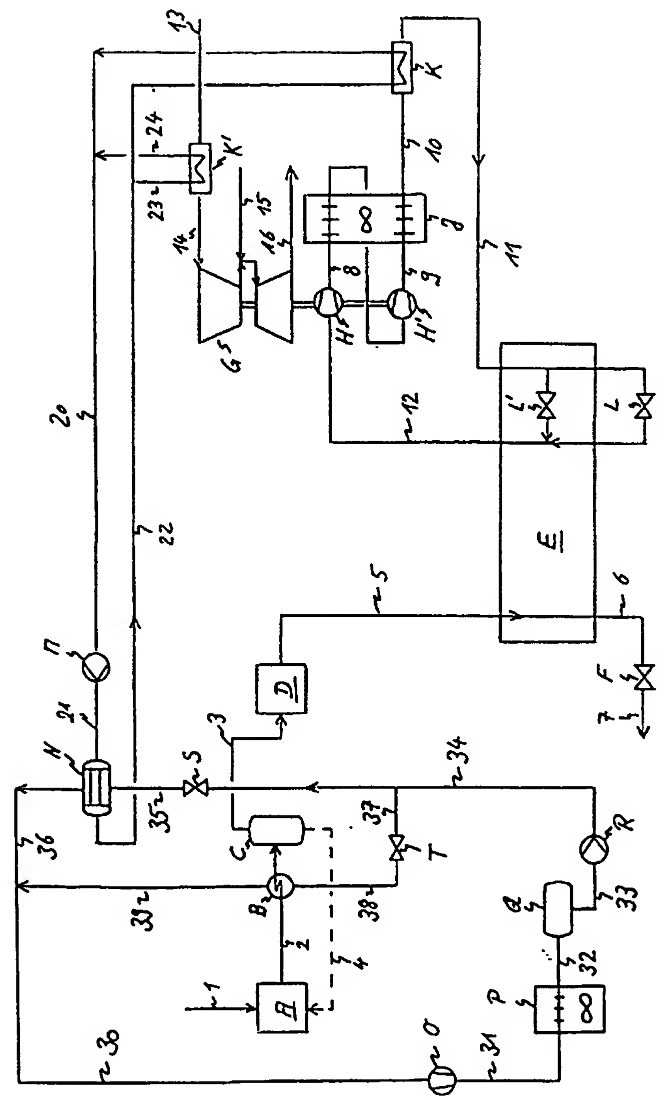
FIG.1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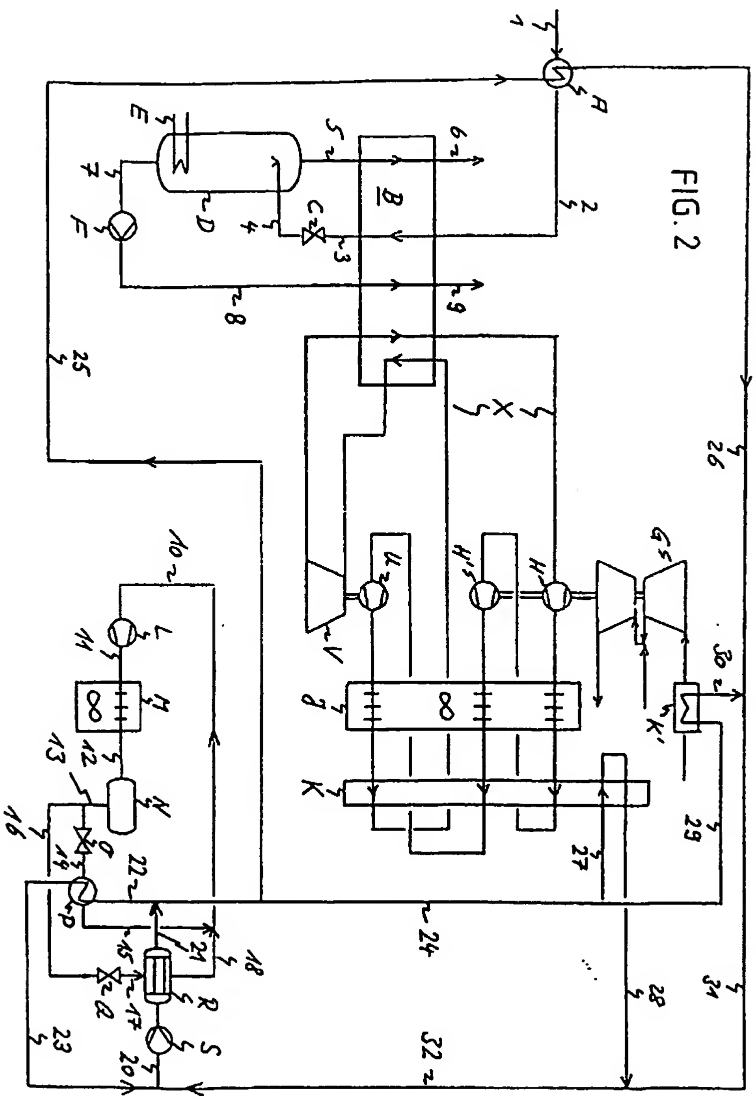

FIG. 2

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